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Bouwmeester, Maaike; Scholtens, Bert

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Maaike C. Bouwmeester
Bert Scholtens

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Research Institute SOM
Faculty of Economics & Business
University of Groningen

Visiting address:
Nettelbosje 2
9747 AE Groningen
The Netherlands

Postal address:
P.O. Box 800
9700 AV Groningen
The Netherlands

T +31 50 363 7068/3815

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Maaike C. Bouwmeester
Department of Economics, Econometrics and Finance
Faculty of Economics and Business, University of Groningen
m.c.bouwmeester@rug.nl

Bert Scholtens
Department of Economics, Econometrics and Finance
Faculty of Economics and Business, University of Groningen

Cross-border spillovers from European gas infrastructure investments

Maaike C. Bouwmeester[a*] & Bert Scholtens[a,b]

October 2014, updated version (Figure 4 and 5, Table 6)

Abstract

We investigate international investment in natural gas infrastructure. In particular, we analyze cross-border cost spillovers related to the investment expenditure of five European countries in a multi-regional input-output model. Value added coefficients and employment coefficients are used to translate the impacts into employment compensation, capital compensation and employment hours required. We find that spillovers are generally larger for employment compensation compared to capital compensation, that the spillovers primarily flow to a limited set of countries, and that most employment hours are created for medium skilled-labor. Hence, we suggest that investment plans should not be assessed from a national perspective, but from an EU perspective.

Keywords: natural gas, gas transmission, investment assessment, energy policy, multi-regional input–output modeling, European Union

JEL codes: C67, D57, L71, L95, Q43.

[a] Department of Economics, Econometrics and Finance, Faculty of Economics and Business, University of Groningen, The Netherlands

[b] School of Management, University of Saint Andrews, UK

[*] Corresponding author, E-mail: m.c.bouwmeester@rug.nl, Phone: +31 50 363 7974, Faculty of Economics and Business, University of Groningen, PO Box 800, 9700 AV Groningen, The Netherlands.

1 Introduction

Different EU energy market projections show large variations in future gas flows, with some even predicting a decline in the total flow. However, most models foresee significant local demand growth in certain regions (Smith, 2013). To facilitate these flows additional transport and storage facilities are required (European Commission, 2010b). One of the bottlenecks in the current infrastructure is the lack of interconnectivity between European countries (European Commission, 2010b; 2012a).

Individual countries try to benefit from the developments by assigning priority to their national gas sector for which they define mainly domestic infrastructural strategies. Moreover, the investment plans are generally assessed at the national level only.[1] The economic impact in other countries is usually included in the national investment analysis as negative leakage (Eijgenraam et al., 2000). International spillovers therefore tend to be ignored. Due to the recent turmoil in the Ukraine, politicians in Europe now realize that their dependency on gas has a large international dimension and that international collaboration might be helpful. This warrants attention for the international effects of gas infrastructure investments.

Due to globalization, large-scale gas transmission investment expenditures entail large cross-border indirect effects. At a European level, from the viewpoint of an overall cost-benefit analysis, these effects do not have an impact in case of a perfect market. However, despite the European single market, current labor and financial markets in Europe are still plagued by imperfections. This suggests that the indirect cross-border effects need to be accounted for. In addition, investments have distributional effects, both in geographical terms and across production factors like labor and capital, which need to be considered when assessing investment plans.

The European Union (EU) has called for the development of EU-level methodologies to assess projects of common interest (European Union, 2013). A draft set of methodologies has very recently been submitted the European Network of Transmission System Operators to the European Commission (ENTSOG, August 2014). The proposed set of methodologies does not incorporate a methodology or suggestion how to estimate the (indirect) effects related to the capital expenditure. In this paper, we propose a methodology that is able to track the impacts along the respective international value chains. We also show that the methodology allows reporting on the size and distribution of the cross-border spillovers by country (and by sector) of impact. The estimated cross-border spillovers of a selected set of investment plans are shown to be relatively large.

Our main research interest is to establish the cross-border indirect effects of an investment stimulus, in terms of economic impacts in other countries than the country where the initial economic stimulus takes place. We use a multi-regional input-output (MRIO) model to estimate the cross-border spillovers (Miller and Blair, 2009). Elsewhere in the literature, the same methodology has been used to estimate trade in value added and represent global value chains (e.g. Johnson and Noguera, 2012; Backer and Miroudot, 2013; OECD, 2013; Los et al., 2014; Koopman et al., 2014; Timmer et al., 2014). In this paper, we investigate the indirect cross-border impact of investment expenditures related to gas transmission infrastructure. We are the first to trace investment

[1] The EU has instructed the European Network of Transmission System Operators for Gas and Electricity to develop methodologies for a harmonized energy-system wide cost-benefit analysis at Union level for projects of common interest (EU Regulation No. 347/2013, Guidelines for trans-European energy infrastructure, Article 11). These are currently in development.

expenditures along the respective value chains of the sectors supplying the investment goods, where we distinguish between domestic impacts, impacts in other EU countries, and non-EU impacts.

We analyze expected cross-border spillovers related to the investment plans of five European countries, as published in the Ten Year Network Development Plan (TYNDP) of the European Network of Transmission System Operators of Gas (ENTSOG).[2] The countries included are Austria, Belgium, France, Germany and the Netherlands. The investment plans are first turned into cost estimates, which are then allocated to the sectors serving the investment demand. The investment demand estimates are combined with an MRIO model to trace out the distribution of the impacts over countries. Value added coefficients and employment coefficients are used to translate the impacts into employment compensation, capital compensation and employment hours required. The multi-regional input-output model is calibrated with data from the EXIOPOL database[3], which provides input-output relations for the year 2000. The set-up of the EXIOPOL database is discussed in Tukker et al. (2009) and environmental footprint analyses performed with this database are described by Tukker et al. (2013), Bouwmeester and Oosterhaven (2013), and Schoer et al. (2013).

In general, we expect the cross-border spillovers to other EU countries to be a minor part of the total impact of gas infrastructure investments. However, for relatively small countries the cross-border impacts are expected to be larger due to their higher degree of international openness. We are also interested in the distribution of the impact. Any cross-border impacts are most likely to occur in the largest trading partners of the countries. Knowledge on the size and distribution of the cross-border spillovers may aid the discussion of who should contribute to financing the investment, especially when it is a project of EU-wide importance.

This research is related to other multi-disciplinary studies that analyze and propose widely diverging strategies to assess investment plans related to energy infrastructure. An early contribution is Bergendahl (1988) who studies whether gas capacity expansion into new regions is profitable from a social point of view. A stepwise procedure is proposed, where first the optimal size of the investment is determined based on demand at different locations along the pipeline, followed by an analysis whether the return is acceptable. De Nooij et al*.* (2010) devise a cost-benefit framework following a change in the relevant regulation, which now allows for ignoring a technical rule for electricity grid design if the costs exceed the benefits. Their framework allows them to establish that the costs of the technical rule most likely outweigh the benefits if it would need to be upheld during periods of maintenance. Other papers focus on investment planning under the uncertainty of feed-in due to intermittency of renewable energy resources. For example, Neuhoff et al*.* (2008) use linear programming to select investment options by optimizing system dispatch given assumptions on security requirements, fuel and other costs including environmental costs, and transmission possibilities. Their results on technology choice, investment volume, and regional distribution change substantially when they assume that unlimited transmission capacity is available, highlighting the importance of transmission constraints in investment pattern modeling. Spiecker et al. (2013) also present an approach that allows the assessment of interconnector investments given the presence of intermittency and endogenous power plant investments. These models all focus on an optimal configuration of the network given quantities related directly to the functioning of the

[2] ENTSOG TYNDP 2013-2022, available at: http://www.entsog.eu/publications/tyndp/2013#ENTSOG-TEN-YEAR-NETWORK-DEVELOPMENT-PLAN-2013-2022, last accessed: 9-Dec-2013.

[3] EXIOPOL is the acronym representing the project: 'A new environmental accounting framework using externality data and input-output tools for policy analysis'. The project was funded under Framework Programme 6 of the European Union. For more information see: http://www.feem-project.net/exiopol (accessed 05-Sept-14).

network and disregard the impact of the investment itself on the wider economy. Harris et al. (2010) study the impacts of a Dutch gas hub strategy using an input-output model for the Dutch economy, effectively assuming that all imports are produced with Dutch technologies and ignoring cross-border effects.

We contribute to this literature on investment assessment by presenting a method that accounts for analyzing the size and distribution of the cross-border impacts associated with investment expenditure. We find significant differences between countries regarding the impact of investment on domestic value added and the cross-border leakages to other countries. The distribution of the intra-EU cross-border spillovers is concentrated and affects a few countries only. We also find that the impact on employment can be differentiated along skill levels and that these are not evenly distributed. In the next section, we first give background information related to large-scale EU gas infrastructure investment plans, before we turn to a description of our method, data and results.

2 Towards an integrated EU gas market

The analysis of gas infrastructure investments should be seen against the background of recent developments in the gas market. This section describes the wider setting by discussing the changes, many of which were instigated by the European Commission. It describes the role of the EU and how it steers investments by defining priority corridors, compiling TYNDP and offering financial facilities.

Energy policy is listed high on the agenda of the EU. The EU has specifically focused on creating an integrated internal energy market and on ensuring the security of energy supply. Working towards either objective requires adjustments of the institutional framework (regulation, policies) and technical alterations (investment in additional pipelines and storage to increase both capacity and flexibility). A recent development in the gas sector has been the EU-wide unbundling of utility companies into trading companies and transmission system operators (TSOs). Competition among the trading companies is facilitated by the rules and regulations that aim to create a well-functioning internal market for gas. At the European level, regulations and directives have been adopted to guide the creation of the European internal gas market (European Commission, 2011a; 2011b; European Union, 2010).[4] In contrast, the gas transmission operators were continued as state-owned enterprises under stringent regulation. These companies are natural monopolists due to the high investment cost of installing gas transport infrastructure (Joskow, 2007). The gas infrastructure in place has to facilitate an efficient matching of supply and demand of gas.

To create an internal market for energy, the energy sector has been extensively liberalized and utility companies have been privatized. Whether and to which extent European national gas markets are integrated is subject of several studies. Siliverstovs et al. (2005) for example find high integration of the intra-EU gas market; although they conclude against an integrated world gas market. An integrated market is also thought to ensure security of supply by facilitating the unhindered flow of gas. Even though the current market is largely integrated, security of supply is still of great concern (Weisser, 2007; European Union 2010). Comparing security of supply indexes, Le Coq and Paltseva (2009) conclude that more countries have a relative large security of supply risk with respect to gas, compared to oil and coal supplies.

[4] See also the European Commission website dedicated to the 'Single market for gas and electricity'; http://ec.europa.eu/energy/gas_electricity/index_en.htm, last accessed: 9-Dec-2013

Investing in infrastructure extensions is one of the instruments to increase the security of supply and to enhance competition. Low security of supply is in most cases due to a large dependence on one source and limited connectivity to the central and denser gas transmission network. To address security of supply issues the European Union calls for more diversification in gas sources and hence transmission pipelines, and an increase in interconnection capacity (European Commission, 2011a). Bottlenecks in the current infrastructure mainly exist at national borders (European Commission, 2010b; 2012a). In the future one interconnected European network should provide the necessary transmission capacity to service the internal market. Additional infrastructural capacity and flexibility is planned to strengthen the network integration (European Commission, 2010a). Competition can also be enhanced via transport capacity investments through their impact on market structure (Gasmi and Oviedo, 2010).

Further transmission investments are warranted in case an increase in the demand for gas is expected. Projections of gas demand show increasing gas flows in about half of the scenarios included in a meta-study by Smith (2013). He finds that the difference between declining or rising demand hinges mostly on assumptions related to displacement rates. This can be the rate at which fossil fuels will be displaced by renewables and/or nuclear generation, or the rate at which gas will displace other fossil fuels as a fuel for electricity generation. Other arguments that point at an increase in the demand for gas are the low carbon content of gas compared to other fossil and the flexibility in production (scalability) promoting it as a fall back option when intermittent renewables take up larger shares of the energy market. In addition, European domestic production is expected to decrease due to dwindling reserves.[5] Higher demand coupled with decreasing domestic production will inevitably result in higher import flows. The transmission of these gas flows from outside the European Union to the different nations will require additional investments. Even when aggregate EU gas demand growth is projected as moderate, or even negative, the differences across nations can be significant. Adequate transmission capacity and flexibility to these specific regions will still need to be ensured (Smith, 2013).

Transmission investment decisions are ultimately made by TSOs. The risk related to gas infrastructure investments lies mainly in uncertainty about demand for transport services in the future. These risks are mitigated by getting gas traders to commit to transport flows through long-term contracts before the final investment decision is taken.[6] Only when a sufficient percentage of the transmission capacity is sold the investment will be undertaken. This process of subscription to long-term contracts is referred to as an Open Season. These are periodically organized by TSOs or infrastructure companies to estimate demand for capacity for the next decade and beyond. If the results show that the increase in capacity demand will encounter bottlenecks in the infrastructure, a business case for the investment is built. The subscribers to the open season then have to commit to a long-term contract. A detailed description of this process as currently applied by the Dutch TSO can be found in Gasunie Transport Services (2011).

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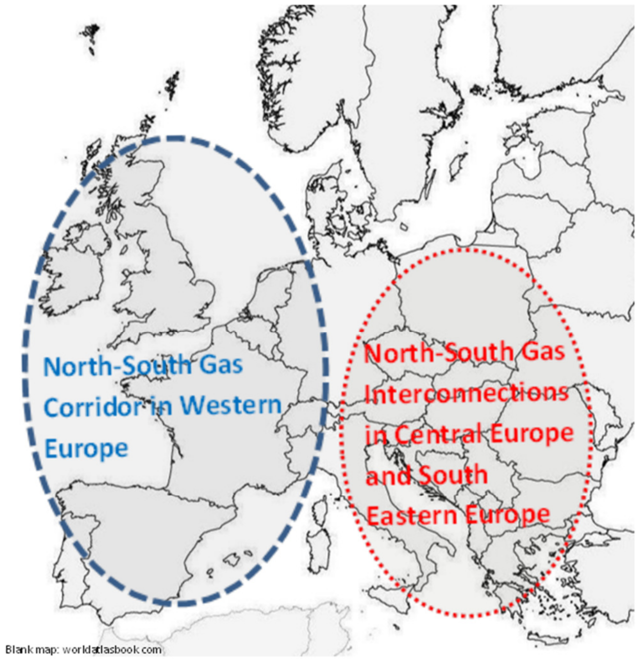
[5] Shale gas may increase these reserves, but European development of the related production technique is only very hesitantly undertaken. There are alleged environmental issues that need to be covered, like the possible contamination of drinking water, and the claim that the technique leads to an increased incidence of earthquakes. Another issue is the large quantity of boreholes required by the technique compared to the exploitation of a standard gas field, which may be hard to realize in densely populated areas in the EU.

[6] A downside of long-term contracting is the barrier it forms for new entrants to the market. Companies buy transmission capacity based on estimates that may not be realized. Or companies might buy capacity in order to block competitors. To mitigate these problems so called use-it-or-lose-it rules and use-it-or-sell-it rules have been instated.

At the EU level provisions are underway to facilitate a well-balanced process of investment decision making. In addition to infrastructural projects undertaken with private funds, the European Union stresses the need for further investments in infrastructure. This has led to the formulation of priority interconnection plans (European Commission, 2011a). These lists especially target international infrastructural projects and interconnectors in order to promote diversification, short-term gas deliverability, security of supply, and to end isolation. The differences between nationally instated regulations and policies often make these projects especially risky (European Commission, 2012b).

The European Union has also set up a financial facility to support targeted infrastructure investment (European Commission, 2011b). Of the total budget of € 50 billion for 2014-2020, € 9.1 billion is reserved for energy infrastructure investment. It is estimated that € 2.9 billion will be required to leverage gas infrastructure investments, of which investments will fall short by an estimated amount of € 16 billion. The amount needed to leverage gas infrastructure investments is estimated to be € 100 million for the West Europe corridor and € 1 billion for the Central Europe corridor (European Commission, 2012c). These corridors are depicted in Figure 1. An objective assessment of each investment plan is required in order to ensure that social welfare is maximized. It is crucial that this assessment is done from an EU-wide viewpoint, to properly account for cross-border effects and ensure system-wide optimality, both in the short terms and in the long term.

Figure 1: Two priority corridors for gas infrastructure investment



To coordinate large-scale gas transmission investment plans and keep track of the progress of interconnection, the EU has decided to ask the European Network for Transmission System Operators of GAS (ENTSOG) to compile Ten Year Network Development Plans (TYNDP). The 2011-2020 TYNDP lists projects for a total value of 89.3 billion euro (European Commission 2012d). The largest share (80%) of the costs of investment plans included in the TYNDP concern relates to transmission projects, where the remaining 20% consists of storage and LNG projects. In terms of cost shares, for 75% of the projected costs the final investment decision has not yet been taken.

Next to the biannual EU TYNDP, TSOs also have to publish Gas Regional Investment Plans, which promote further regional cooperation (European Commission, 2009)

Investment plans also needs to be assessed with regards to the optimal configuration of the network. This holds especially for projects of common interest. Developments at the EU level are now at a stage where a framework is devised to assess investment plans in light of one integrated EU gas infrastructure. The EU proposes using an energy system-wide cost-benefit analysis and has requested ENTSOG to develop the methodology (European Union, 2013). Recently, ENTSOG has submitted an energy system wide methodology to the European Commission to be approved (ENTSOG, August 2014). The proposed set of methodologies does not incorporate a method of how to estimate the indirect effects and cross-border spillovers related to the investment expenditure itself.

3 Method and data

Investing in large-scale infrastructure projects creates international spillovers. A nationally focused assessment of the impacts usually includes an estimation of the total amount of investment expenditure that leaks away from the country. This estimate is recorded as a negative effect, without further assessing where the money flows to (e.g. which country, sector, and production factor). In this paper, we focus specifically on the international linkages. From an EU perspective, flows to other EU countries should not be seen as negative effects. The scope of the investment analysis therefore needs to be expanded. We estimate investment expenditure related to the investment projects presented in the TYNDP and systematically assess the impacts of these different investment plans on each European economy via multi-regional input-output modeling (MRIO).

3.1 International input-output modeling

A multi-regional input-output model is the most appropriate framework to assess cross-border direct and indirect impacts of spending (Miller and Blair, 2009).[7] The underlying data, represented in an MRIO table shows all connections between industries in terms of intermediate deliveries. Consumption by households, the government and capital formation (investment) enter the model exogenously. The direct and indirect additional production required to produce the exogenous final demand can be calculated by summing over all additional intermediate products required. The advantage of the model is its inclusive scope and its detail; the complete economy is represented in an integrated network of industries. Analyzing effects of final demand shocks provides a full picture of the economy wide effects.

In the present paper, the vectors representing demand packages for infrastructural expenditures are used as demand shocks in MRIO modeling. The impacts in terms of value added generated can be traced to the respective countries that contribute at some stage, possibly only indirectly, to the production process of the investment goods. In an analysis using the same basic method, Wiedmann et al. (2011) incorporate all investments in wind energy generation capacity as standard (yearly)

[7] These impacts can range from value added impacts to environmental impacts. Interest in computing indirect effects in an MRIO framework has recently resurged with a focus on production factors investigating global value chains (e.g. Koopman et al., 2010; Johnson and Noguera, 2012, OECD, 2013; Los et al., 2014; Koopman et al., 2014; Timmer et al., 2014) and with a focus on the environment (for CO_2 see e.g. Davis and Caldeira, 2010, Davis et al., 2011; Peters et al., 2011; Peters et al., 2012; Kanemoto et al., 2014, for materials see e.g. Bruckner et al., 2012, Wiedmann et al., 2014).

production inputs. With the very long lifetimes of gas infrastructure investments, and the limited construction period of two to four years, this representation is problematic for an interpretation of the results over time. In reality, the expenditure is concentrated in the first period, with low expenditure during the rest of the lifetime of the project. Recently several reports have been published on the impact of infrastructure investment using input-output models to inform policy makers in the U.S. (Cohen et al., 2012; Department of the Treasury & Council of Economic Advisers 2012; Lahr et al., 2010 Heintz et al., 2009). Our approach extends the method used in these reports by making use of an MRIO table instead of a national table, in order to trace the international spillovers.

Over the recent decade, much effort has been put towards compiling input-output databases that incorporate a large set of countries and all international trade links between industries in different countries, e.g. MRIO tables (Tukker and Dietzenbacher, 2013). In addition to representing all national intermediate inputs used by each industry, the international (imported) inputs are registered in detail as well. These databases allow the calculation of impacts across national borders and investigations into international production processes and global value chains.

The input-output identity is mathematically represented as follows, where bold capital letters represent matrices and bold small-cap letters denote column vectors:

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{f} \; . \qquad \textbf{(1)}$$

Matrix $\mathbf{A}$ shows all intermediate purchases by buying industry *j* and selling industry *i* as share in total inputs of the buying industry. Along the columns and rows, the same set of industries is listed, where along a column, all purchases of an industry over one year are recorded, and in a row, all sales of an industry over one year are recorded. Vector $\mathbf{x}$ contains the values of output per industry and vector $\mathbf{f}$ represents the vector of exogenous final demand.

Solving Equation 1 for $\mathbf{x}$ gives the input-output model:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} \; , \qquad \textbf{(2)}$$

where $\mathbf{I}$ is the identity matrix of the same size as $\mathbf{A}$. The solution is also often represented as $\mathbf{x} = \mathbf{L}\mathbf{f}$. An element of the matrix $\mathbf{L}$ denoted with the indices $i = 1 \cdots I$ and $j = 1 \cdots J$ shows the direct and indirect additional output of industry i required to produce one more final product j. More information on the model, its background, mathematical properties and underlying assumptions can be found in Miller & Blair (2009).

This fundamental model can be used to represent one country, but it can also incorporate many countries. In case multiple countries are distinguished two more indices are added: $r = 1 \cdots R$ to represent the country of origin and $s = 1 \cdots S$ to represent the country of destination. In this vectors $\mathbf{x}$ and $\mathbf{f}$ have $R * I$ elements and $\mathbf{L}$ is of dimensions $R * I$ by $S * J$.

In this paper, we use information on investments to specify a vector $\mathbf{c}$, which represents the expenditure on goods and services following an investment plan for gas infrastructure. The role of this vector is analogous to vector $\mathbf{f}$, but we use $\mathbf{c}$ to distinguish it from total final demand by all categories, which also includes demand by households, government and change in inventories.

To focus on more standard measures of economic activity than gross output, we calculate the impact in terms of value added and employment effects. For the value added effects, we use a vector $\mathbf{w}$ that represents the value added in terms of value added by labor per unit of output, and vector $\mathbf{v}$ that represents value added by capital per unit of output. Our results are calculated as follows. Value added by labor is given by:

$$w = \mathbf{w}'\mathbf{Lc}, \tag{3}$$

and value added by capital is calculated by:

$$v = \mathbf{v}'\mathbf{Lc}, \tag{4}$$

where the symbol ' denotes the transposition of the vector noted before the symbol. In our analysis we use an international input-output model, which allows us to break down the results on value added generated to identify the country where the final demand is generated.

Second, we also look at employment. Now we use a vector denoted by $\mathbf{e}$ to represent the employment in hours per unit of production. Analogous to equation 3 and 4 we calculate the result as follows:

$$e = \mathbf{e}'\mathbf{Lc}. \tag{5}$$

3.2 Data

3.2.1 MRIO table

The international input-output data used for this study originates from the EXIOPOL database (Tukker et al. 2009; Tukker et al., 2013). It contains a multi-regional input-output (MRIO) table that represents 43 individual countries and the aggregate region referred to as 'rest of the world' (RoW). For each of these countries and the RoW region intermediate and final demand transactions inside the national borders as well as across national borders are represented. The use of primary factors by each industry in each country is also registered in value terms (i.e. value added by each industry). A distinction is made between value added by compensation of employees and operating surplus (consumption of fixed capital, rents and remaining net operating surplus).

The value of this database over other recent MRIO databases is its detailed industry representation. In total 129 industries are represented for each country, making this database more suitable to trace the effects of expenditure on specific goods and services. This increased detail comes at the cost of having only one reference year (2000) available. However, this study only makes use of input shares and the resulting information on linkages between industries and not the absolute values present in the database. Generally, these input coefficients are taken to be rather stable over longer periods (Miller and Blair, 2009).

In addition to the monetary representation of primary inputs, the use of employment in hours by skill category is available for 20 of the 27 EU countries. The skill categories that are distinguished are:

high-skilled, medium-skilled and low-skilled. The quantity data on primary factors is not an integral part of the input-output table, which only contains flows in value terms. These data are part of extensive satellite accounts that also contain information on a host of environmentally relevant data.

3.2.2 Investment data

To connect the investment costs to an input-output model, the expenditure on the final investment goods bought needs to be defined. This paper is primarily showcasing the strengths of an impact study performed with a multi-regional input-output modeling. When used to calculate the indirect effects of an investment project, all relevant investment costs will be known in detail. In case several detailed investment scenarios need to be compared, as in a social cost-benefit analysis, care must be taken to work with detailed expenditure estimates. Our present aim is to show what type of information can be derived from undertaking this exercise.

For this purpose, a set of projects across five countries has been translated into expenditure estimates. These five countries are selected, because they are important gas transit countries and centrally located within the EU. The countries selected are Austria, Belgium, France, Germany, and The Netherlands. These countries are outlined in Figure 2 and Figure 3. Austria, Belgium and Germany score high on both entry and exit capacity, which indicates an important role as international transit country. The Netherlands is primarily an exporting country with relatively high exit capacity, whereas France is an importing country given its larger entry capacity. These countries are clearly centrally located in the European gas transmission network.

Figure 2. Entry capacity gas infrastructure

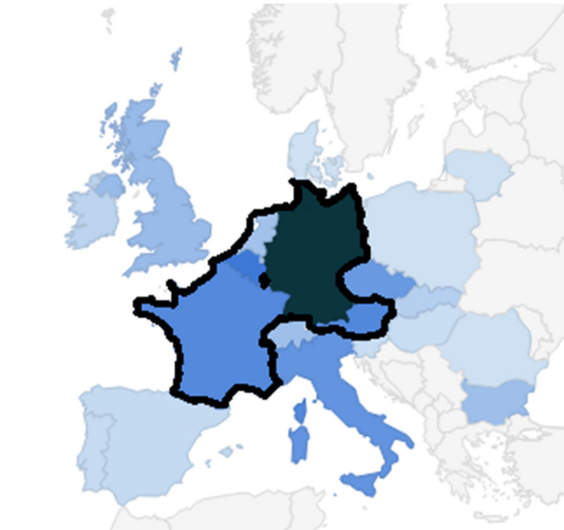
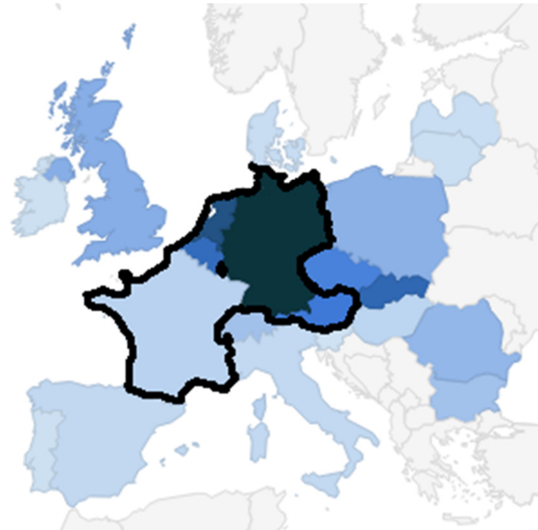


Figure 3. Exit capacity gas infrastructure



Legend: dark(er) shades: high(er) capacity, light(er) shades: low(er) capacity
Source: ENTSOG cross-border transmission capacity (among EU, excl. LNG)

The investment expenditure estimates based on information in the TYNDP is reported in Table 1. The investment plans of the larger countries, France and Germany, are more extensive in terms of absolute values. However, relative to the size of the economy, France plans to invest most. In relative terms, The Netherlands plans to invest more than Germany. The type of investment in which is invested varies much over the countries. Austria and Germany focus largely on transport investment. The coastal countries invest in more LNG, with the exception of Germany. The larger countries invest in underground storage. Only The Netherlands is somewhat of an outlier, with a large focus on additional compression power and investment in underground storage.

Table 1. Investment in million euros by country and project type

M€	Pipelines		Compression		LNG		Underground storage		**Total**	*Total as % of GDP**
Austria	578	(81%)	131	(19%)	0	(0%)	0	(0%)	**710**	*0.4%*
Belgium	159	(29%)	44	(8%)	352	(63%)	0	(0%)	**555**	*0.3%*
France	4751	(47%)	1200	(12%)	2615	(26%)	1550	(15%)	**10118**	*0.8%*
Germany	6726	(76%)	1580	(18%)	0	(0%)	600	(7%)	**8906**	*0.5%*
Netherlands	312	(13%)	854	(37%)	352	(15%)	800	(35%)	**2318**	*0.6%*

The percentage between brackets is the share of the project type investment in total investment.
* GDP at basic prices (= total gross value added), source: EXIOPOL database. Note that the GDP reference value pertains to one year, whereas these investment plans cover a 10-year period.

These estimates are roughly in line with the estimates of the EU of the amount of investment required in the Western European corridor, which are estimated at 20 billion Euros (European Commission, 2012d, p.8). Austria is part of the Central European corridor, where the total investment need is estimated to be 26 billion Euros. These approximate figures are from calculations made by the European Commission's DG ENER based on data from the model PRIMES. PRIMES is a partial equilibrium model for the European Union energy markets, used for forecasting, scenario construction and policy impact analysis up to the year 2030 (European Commission, 2012c).

The investment bundles need to be translated into expenditure on final goods and services that can be linked to the MRIO table. For this purpose, allocation percentages have been estimated that can distribute the investment expenditures by project type over the industries that deliver the required goods and services. The percentages indicate the share of investment expenditure spend in the sector indicated. Investing in pipelines mainly implies a need for construction effort and materials. Compression and LNG investment requires more machinery and equipment. The allocation percentages used are represented in Table 2.

Table 2. Allocation percentages

	%	Pipelines	Compression	LNG*	Underground storage†
i28	Fabricated metal	21%	35%	35%	25%
i29	Machinery & equipment	8%	14%	14%	10%
i45	Construction	51%	31%	31%	30%
i60.2	Transport	6%	6%	6%	10%
i65	Financial services	3%	3%	3%	5%
i66	Insurance and pension funding	3%	3%	3%	5%
i70	Real estate activities	5%	1%	1%	1%
i74	Business services	4%	8%	8%	14%

* Due to lack of data on LNG investment, the percentages for compression power are also used for LNG.
† With minor adjustment adopted from Brattle (2010).

The final investment demand packages are shown in Table 3. The input-output data also contains information about the international distribution of total investment demand. That information is used in terms of shares to distribute the final investment demand packages of Table 3 over different source countries. The distributed investment packages represent the *direct* impact of investment expenditure on output in the listed sectors in all countries that supply these final investment goods and services. By means of input-output modeling, these direct impacts can be traced back to the value added impacts, through the full chain of intermediate supply relations.

Table 3. Allocation of investments to sectors in million euros

	M€	AT	BE	FR	DE	NL	**Total**	*Total %*
i28	Fabricated metal	165	171	2702	2089	686	**5813**	*25.7%*
i29	Machinery & equipment	66	68	1081	836	274	**2325**	*10.3%*
i45	Construction	333	202	4041	4067	768	**9412**	*41.6%*
i60.2	Transport	42	32	655	547	168	**1444**	*6.4%*
i65	Financial services	21	16	328	273	84	**722**	*3.2%*
i66	Insurance and pension funding	21	16	328	273	84	**722**	*3.2%*
i70	Real estate activities	28	10	262	335	28	**664**	*2.9%*
i74	Business services	34	38	721	486	224	**1503**	*6.6%*
	Total	**710**	**555**	**10118**	**8906**	**2318**	**22606**	*100%*

In the appendix to this paper, we discuss in more detail how the investment expenditure has been estimated. First, we estimated unit costs by using information on investment expenditure and technical information from the TYNDP. For example, a total investment sum of 171 million euro for 100 km pipeline of 90 cm diameter results in a unit cost of 1.71 M€/km for the 90 cm pipeline. These estimates were complemented by information from external sources that have published unit cost of different types of gas infrastructure investment. From the range of unit cost estimates we obtained in this fashion, we calculated an average unit cost that was used in our analysis. From the unit cost estimates, we derived total expenditure estimates by using the information on the quantity installed from the TYNDP (length of pipeline, horsepower, etc.) in combination with the unit cost estimates.

4 Results

Our aim is to provide insight in the economic impacts of gas infrastructure investment expenditure. To compare the magnitude of the impacts and contrast the geographical distribution of the impacts, we will specifically focus on percentages in our analysis and not on the absolute size of the impacts. All five countries represent important nodes in the EU gas infrastructures. We look at the cross-border impacts of their investment expenditure portfolios, which should be considered when deciding on EU support for infrastructural projects. The investment bundle varies over the countries as was described in section 3.2.2.

4.1 Value added generated

We first focus on the direct and indirect value added impacts generated due to the expenditure on gas infrastructure. The specific economic impacts we discuss are employment compensation and gross operating surplus. Both constitute the main income categories of gross domestic product (GDP)[8].

In national accounting, total final demand (GDP from the expenditure perspective) should exactly equal total value added (GDP from the income perspective). The exogenous demand impulse is fully propagated through the interindustry linkages to the sectors where value added is created. This also holds for our investment expenditure demand impulse. The total impact on value added (including taxes less subsidies) is exactly equal to the investment expenditure sum.

The MRIO model allows investigating how the investment expenditure is distributed over the countries affected, the sectors affected, and the type of value added generated. In our discussion, we focus on the countries affected and the type of value added generated. We first discuss the distribution of the economic impact over domestic impacts, impacts in other EU countries, and impacts in non-EU countries. Next, we look into more detail regarding the impacts in other EU countries to specify which other countries benefit most next to the country where the investment takes place.

In Table 4 the distribution of the impact of gas infrastructure investment over type of value added and geographic location is shown. The total percentages of investment impact on employment compensation across the five countries are quite close, the range being from 56% to 60%. The same holds for total impact on gross operating surplus, for which the impacts range from 36% to 39%. For Austria and Belgium, a relatively smaller percentage (56%) flows to employment compensation, than for the larger countries Germany and France (57%). However, in the Netherlands, employment gains relatively most.

Table 4. Distribution of value added generated due to gas infrastructure investment

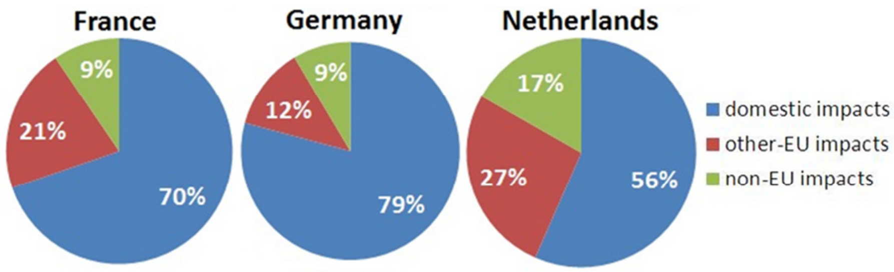
%	employment compensation				gross operating surplus				taxes
	domestic	other EU	non-EU	Σ	domestic	other EU	non-EU	Σ	Σ
Austria	37%	15%	4%	*56%*	26%	10%	4%	*39%*	*5%*
Belgium	31%	18%	7%	*56%*	22%	11%	6%	*39%*	*5%*
France	41%	12%	5%	*57%*	24%	8%	4%	*36%*	*7%*
Germany	47%	7%	4%	*57%*	30%	5%	4%	*39%*	*4%*
Netherlands	36%	16%	8%	*60%*	20%	10%	7%	*36%*	*4%*

Comparing the size of the domestic impact to the impacts in other EU countries, the larger international impacts are associated with the smaller countries, while the domestic impacts generated are relatively small. This is as expected; it is common to find that the larger an economy is, the smaller its international linkages are. The same observation can be made for the non-EU impacts. These are larger for Belgium and Netherlands, and smaller for the other three countries.

[8] To calculate a country's GDP, there are three approaches (Eurostat, 2008). Following the income approach, GDP is calculated as the sum of employment compensation, gross operating surplus, other net taxes on production, and taxes less subsidies on products.

Table 4 shows that Austria has a relatively small percentage impact on non-EU countries for both employment compensation and gross operating surplus. The percentages are equal to those of the larger countries (Germany and France). Although Austria is geographically closer to non-EU countries than Belgium and the Netherlands, the fact that it is landlocked may explain this limited linkage to non-EU countries. Figure 4 shows clearly that The Netherlands is a more open country than Germany or France. The share of non-EU spillovers is the same for these larger countries, but the share of domestic versus other-EU linkages shows that France is more integrated within the rest of the EU than Germany.

Figure 4: Domestic and cross-border shares of value added generated by gas infrastructure investment[9]



In Table 5 the impact in 'other EU' is presented in more detail. In the columns, the countries are represented that invest in gas infrastructure. In the rows the countries are listed where the largest value added impacts occur. These countries represent at least 80% of the impact in other EU countries. Germany turns out to be an important supplier of products and services used as intermediate inputs by the sectors to which investment expenditure is allocated. Of the employment compensation impacts generated in other EU countries because of gas infrastructure investment in Austria, 57% goes to Germany. Of the impacts generated in Germany due to investment elsewhere, the gross operating surplus impacts of investment in Belgium and France are the smallest with 20%. Outside the investor countries, Italy and the UK both benefit relatively much from investments elsewhere. German investment has the lowest total percentages, so relatively much of their investment flows to other EU countries that are not represented in the table.

[9] These percentages are derived from the same data underlying Table 4. Note that the percentages in Figure 4 also include taxes distributed over domestic, other EU and non-EU.

Table 5. The impacts in other EU in more detail

investor	Austria		Belgium		France		Germany		Netherlands	
Impact in:	ec	gos	ec	gos	ec	gos	ec	gos	ec	gos
Austria	—	—	*2%*	*2%*	*2%*	*2%*	**11%**	9%	*2%*	*2%*
Belgium	*3%*	*3%*	—	—	**17%**	**16%**	7%	6%	**15%**	**15%**
France	6%	4%	**26%**	**20%**	—	—	**16%**	**10%**	**12%**	10%
Germany	**57%**	**45%**	**22%**	**20%**	**27%**	**20%**	—	—	**34%**	**28%**
Italy	10%	**18%**	6%	**13%**	**12%**	**19%**	**13%**	**20%**	6%	**12%**
Netherlands	*3%*	*3%*	**15%**	**14%**	**11%**	**11%**	9%	9%	—	—
Poland	*2%*	*3%*	*1%*	*1%*	*1%*	*1%*	4%	6%	*1%*	*2%*
Spain	*2%*	*2%*	5%	6%	9%	9%	6%	6%	*3%*	4%
Sweden	*2%*	*2%*	*2%*	*2%*	*3%*	*3%*	4%	*3%*	5%	5%
UK	5%	5%	**13%**	**10%**	**13%**	**10%**	**13%**	10%	**12%**	**10%**
Total	89%	85%	92%	88%	93%	91%	83%	80%	92%	89%

* ec = employment compensation, gos = gross operating surplus
Values larger than 10% are in bold face. Values lower than 3.85% are in italic font. The value 3.85% is 100%/26, the percentage each country would be associated with in a completely equal distribution over all 26 EU partner countries. Only countries with at least one value over 3.85% are represented here.

4.2 Employment impacts

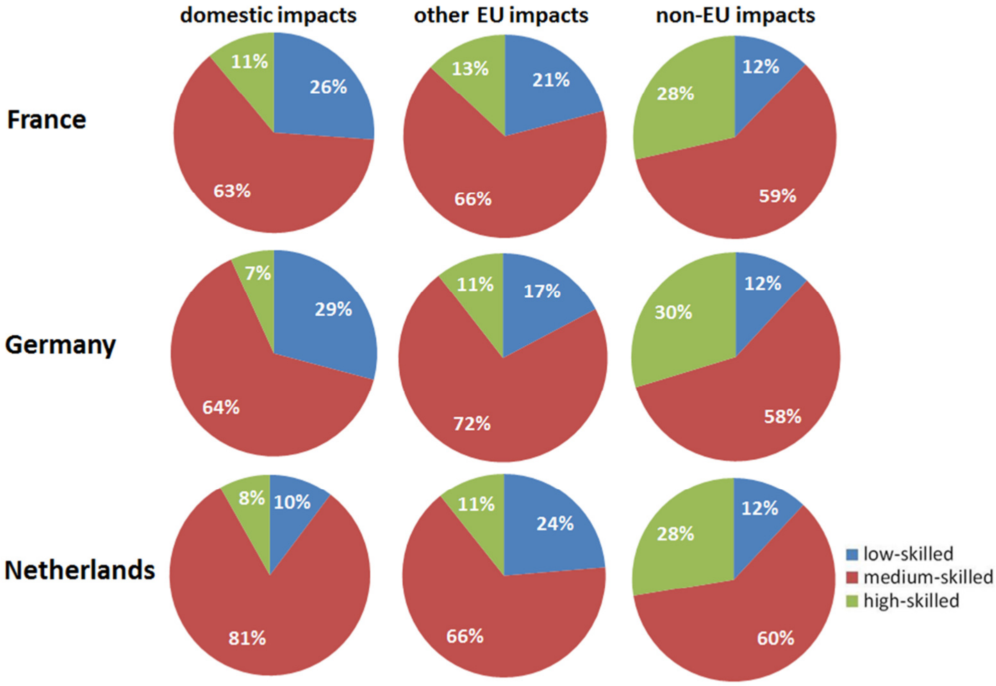
In addition to looking at income effects, we also analyze the effects in terms of hours of employment generated. The impact on employment is differentiated with respect to skill level. We discern impact on hours of employment of high-skilled labor, medium-skilled labor, and low-skilled labor.[10] The results can be found in Table 6.

In all of the investing countries, the investment generates chiefly medium-skilled job hours. The Netherlands has relatively little additional low-skilled labor, especially when comparing the domestic impact of investment. Of Belgian investment, only 51% of the labor hours generated is within the country itself. Of the cross-border impacts, 42% is in other European countries, and 7% is in non-EU countries. The employment impacts of The Netherlands are for 7% in non-EU countries, while Austria, France and Germany only generate 2% to 3% of the job hours in countries outside the EU. As with the value added results, France and Germany keep most of the employment impact within their own borders, 71% and 76% respectively.

In Figure 5, we focus on the employment impacts by skill-level in relation to the geographical destination. For all countries, the other EU impacts and the non-EU impacts are in terms of shares remarkably the same. Only in Germany, the share of medium-skilled employment hours generated in other EU countries is slightly higher than other countries, whereas low-skilled labor in the rest of Europe benefits less from German investments. The largest difference in terms of labor composition is found for the domestic impacts. In The Netherlands, most additional hours of employment are taken up by medium-skilled labor.

[10] The EXIOPOL data on different types of labor are taken from the EU-KLEMS database. In general the levels are defined as follows: high-skilled equals a university degree, medium-skilled: higher professional and vocational education (secondary level), lower-skilled: all up to lower secondary education. Full information on the definitions used are given in Timmer *et al.* (2007), pp. 28-29. The documentation is available at (last accessed 9-Dec-2013): http://www.euklems.net/data/EUKLEMS_Growth_and_Productivity_Accounts_Part_I_Methodology.pdf

Figure 5: Shares of employment hours by skill-level



In Table 7, the impact in other EU countries is shown in more detail. The impacts in terms of employment hours are more diverse than the value added results. The countries included here that are not included in Table 5 (Czech Republic, Hungary, Poland, Portugal, Slovak Republic and Spain), possible supply labor at relatively low wage rates. Again, Germany benefits relatively much from gas infrastructure investment in each of the four other investor countries. France and the UK are impacted by investment in each of the investor countries, except in the case of investment in Austria. Austria is clearly more linked to countries in Eastern Europe, which, to some extent, also holds for Germany. Also for employment hours, gas infrastructure investment expenditure by Germany is least concentrated.

In all result tables, we only represented the distribution of the impacts. A larger or smaller value of investment expenditure will not change this distribution. However, changes in the allocation percentages of the types of expenditures to the sectors that supply the goods and services will have an impact. Different sectors have different links to other industries and to other countries. If the contribution of a certain sector increases or decreases compared to another sector, this will have an impact on the distribution. The less alike two industries in their intermediate input pattern, in terms of industries delivering or countries exporting the inputs, the larger will be the difference in the outcomes.

Table 6. Employment generated* by skill-level, in million hours

	low skilled			medium skilled			high skilled			total
	domestic	other EU	non-EU	domestic	other EU	non-EU	domestic	other EU	non-EU	(million hours)
Austria	15%	7%	0%	44%	24%	1%	5%	3%	1%	26
Belgium	20%	9%	1%	26%	28%	4%	6%	5%	2%	16
France	18%	5%	0%	44%	17%	2%	8%	3%	1%	304
Germany	22%	4%	0%	49%	15%	2%	5%	2%	1%	285
Netherlands	6%	7%	1%	51%	20%	4%	5%	3%	2%	76

* Data for seven EU countries are missing: Bulgaria, Cyprus, Estonia, Latvia, Lithuania, Malta, Romania. Employment effects generated in these countries are not included in the numbers for 'other EU'.

Table 7. Employment generated in other EU countries*, by skill-level, in million hours

investor	Austria			Belgium			France			Germany			The Netherlands		
impact in:	l-s†	m-s†	h-s†	l-s	m-s	h-s	l-s	m-s	h-s	l-s	m-s	h-s	l-s	m-s	h-s
Austria	—	—	—	2%	2%	1%	2%	2%	1%	9%	7%	5%	2%	3%	2%
Belgium	3%	1%	2%	—	—	—	**15%**	10%	**18%**	7%	2%	4%	**17%**	9%	**13%**
Czech Rep.	5%	**11%**	10%	1%	3%	2%	1%	3%	1%	8%	**15%**	**11%**	2%	6%	4%
France	4%	3%	5%	**22%**	**20%**	**24%**	—	—	—	**11%**	7%	10%	10%	10%	**12%**
Germany	**56%**	**32%**	**27%**	**26%**	**17%**	**12%**	**30%**	**20%**	**13%**	—	—	—	**36%**	**27%**	**18%**
Hungary	9%	9%	**13%**	2%	2%	3%	2%	2%	2%	9%	8%	10%	2%	3%	3%
Italy	0%	**15%**	6%	0%	**13%**	5%	1%	**23%**	7%	1%	**15%**	6%	0%	**13%**	4%
Netherlands	1%	3%	2%	6%	**16%**	10%	3%	**11%**	9%	3%	6%	4%	—	—	—
Poland	3%	7%	7%	2%	5%	4%	1%	4%	2%	10%	**17%**	**15%**	3%	7%	5%
Portugal	1%	0%	0%	6%	0%	1%	7%	1%	2%	7%	0%	1%	3%	0%	1%
Slovak Rep.	2%	7%	6%	0%	1%	1%	0%	1%	1%	2%	5%	4%	0%	2%	1%
Spain	5%	1%	4%	**15%**	3%	**11%**	**25%**	6%	**19%**	**15%**	2%	9%	9%	2%	7%
UK	2%	4%	7%	7%	**11%**	**17%**	6%	**11%**	**15%**	6%	7%	**11%**	5%	**10%**	**17%**
Total	92%	94%	89%	89%	93%	90%	93%	93%	91%	87%	93%	89%	90%	91%	88%

* Data for seven EU countries are missing: Bulgaria, Cyprus, Estonia, Latvia, Lithuania, Malta, and Romania.

† l-s = low-skilled, m-s = medium-skilled, h-s = high-skilled

Values larger than 10% are in bold face. Values lower than 5.26% are in italic font. The value 5.26% is 100%/19, i.e. the percentage each country would be associated with in a completely equal distribution over the 19 partner countries that have data on employment by skill-level. Only countries for which at least one of the five focal countries has a value of 5.26% for any of the skill-levels are represented here.

5 Conclusion and discussion

We estimate the cost-side impact of investments in gas transmission by quantifying the direct and indirect, national and international impacts on the basis of a multi-regional input-output model. First, we estimate the value of investment projects included in the Ten Year Network Development Plans (TYNDP). The overall budgets for the different plans are subsequently translated into gross fixed capital formation by the industries that manufacture the pipelines, compressor station elements, storage facilities, and interconnectors. The demand stimulus from the investment is traced back through national and international value chains to the impact on value added and employment in each of the countries affected. The relative importance of the flows for the countries is shown to vary much. In terms of additional employment, compensation and gross value added the impacts show in general the same pattern, however, it is quite clear that for smaller countries, the intra-EU impacts are relatively large.

Our analysis strengthens the case for an EU-wide perspective of gas infrastructure investments. Due to uncertainty over energy supply, fuelled by the recent disturbances in the EU's relationship with Russia, the call for a coordinated EU-wide energy policy has increased.[11] Policy makers at the EU-level already focus on developing an integrated international gas transmission network (European Commission, 2010a; European Union, 2013). Within this network, main connection routes may emerge. Given the large extension projects and the increased density of the European gas network, forces are at play that may result in a shift in power that can be derived from these gas flows. Countries with large transit flows may be better able to ensure the security of supply. The same holds for countries with diversified sources and multiple interconnectors. Several countries have indicated they want to pursue a nodal function in this network. However, investing in the creation of a gas roundabout in each country is sub-optimal. Nevertheless, several national transmission operators focus on a role as regional hub. This usually is strongly supported by national governments in order to secure first mover advantages, develop comparative advantages, stimulate key sectors, and generate employment. The central nodes in the gas infrastructure network will play an important role in managing the gas flows and have a direct influence on security of supply.

However, it is likely that some of the proposed large-scale infrastructural projects are mutually exclusive from an optimal investment point of view. For example, if a strong North-South connection is created in Germany connecting flows from Denmark to France, and alternative connection through The Netherlands and Belgium will be redundant. The current national focus leads to overinvestment, especially if developments in other countries are ignored. To establish at the European level which countries would optimally be the important nodes in the network, a completely internationally focused investment analysis would need to be done. At the moment, the methodology to do this type of analysis is under development (European Commission, 2013). In this paper, we focus on one component which is not yet included in the proposed methodology; assessing the cross-border impacts of investments. Our analysis contributes to a better understanding of the impacts along the international value chain of the expenditure structures related to alternative investment plans. Multi-regional input-output modeling should play a role in

[11] First joint high-level Roundtable on EU Energy Policy European Energy Security Strategy: key priorities and actions, 25 June 2014; http://ec.europa.eu/energy/events/doc/20140625_roundtable_info.pdf, last accessed 16-Sep-2014.

the assessment methodology as it provides detailed sector-level socio-economic impact estimates of the investments by geographical region.

We find that there are pronounced differences between countries regarding domestic value added embodied in investment expenditure and cross-border leakages to other countries. When looking at the distribution of the intra-EU cross-border spillovers, it is clear that the cross-border impacts are concentrated in a few countries. We also show the cross-border impacts in terms of employment compensation, and in terms of hours of employment. Under full employment, the impacts on employment and the subsequent wage effects will cancel out. However, unemployment rates are currently soaring due to the crises and these impacts should therefore be considered.

This paper focuses on presenting the additional information that can be attained from performing an impact analysis through multi-regional input-output modeling. The drawbacks of this method are related to the assumption of fixed input coefficients (both the technology and the trade coefficients) and the limited role of prices. However, most expenditures related to an investment project take place within a couple of years, so rigidity in the input coefficients can be defended. Our study focuses on one important, and often neglected, element of a complete investment assessment. We do not consider the benefits of the investment and the impacts due to operation, and our results therefore do not directly support an investment decision. To extent the cost-side scope, a comparable study could be undertaken after defining the yearly expenses of operation and maintenance. However, as the bulk of gas infrastructure costs are related to the initial investment, our study gives a good first impression of the distribution of the economic impacts of the investment. After the investment project is carried out, the operation and maintenance costs are relatively low. Of course, these should be taken into account when deciding upon alternative investment proposals.

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Supplementary material: Appendix – data preparation

A.1 Introduction

This document describes the estimation process that was used to obtain the gas infrastructure investment estimates. The aim is to estimate investment data on gas infrastructure projects in a format that can be combined with the EXIOPOL multi-regional input-output (MRIO) table. The MRIO table contains data for 44 countries, among which 27 of the EU countries. In addition, each country is represented by 129 industries. For our purposes, five countries have been selected, which are nodes in important gas transmission routes of the EU. Not surprisingly, these countries are centrally located within the EU. The countries selected are Austria, Belgium, France, Germany, and The Netherlands.

A.2 Primary data source

The projects for which investment expenditure is estimated are selected from the Ten Year Network Development Plan (TYNDP) 2013-2022 as published by the European Network for Transmission Systems Operators for Gas (ENTSOG).[12] The Excel file 'Annex A: Infrastructure Projects' has been downloaded to serve as a convenient starting point for collecting additional information required for estimating investment expenditure.[13] Table A.1 shows the number of projects that are listed in the TYNDP 2013-2022 by type of investment, for each of the selected countries.

Table A.1. Distribution of TYNDP projects by country and project type

	Total		Transport	LNG	Storage	Power plant connection	Production facility
Austria	5	*1.7%*	5	0	0	0	0
Belgium	5	*1.7%*	4	1	0	0	0
France	34	*11.6%*	23	5	6	0	0
Germany	15	*5.1%*	12	0	3	0	0
Netherlands	6	*2.1%*	4	1	1	0	0
Total TYNDP	293*		204	45	41	2	1

* 293 is the number of times a country is assigned to a project. There are only 280 unique project codes recorded in the TYNDP. However a few of these projects concern pipelines that cross multiple countries and are therefore assigned to multiple countries.

A.3 Investment expenditure estimation

The TYNPD gives specific and detailed information on gas infrastructure investment plans. However, it does not contain financial information in terms of amounts invested. The MRIO is in value terms, so it requires that the investment data is translated into investment expenditure. In this document we describe first how we selected the relevant projects, followed by a description of the estimation procedure.

[12] http://www.entsog.eu/publications/tyndp#ENTSOG-TEN-YEAR-NETWORK-DEVELOPMENT-PLAN-2013-2022

[13] The original Excel file downloaded was called: 'TYNDP_130221_Annex-A_InfrastructureProjects_FINAL.xlsm'. The Excel file published on July 10th 2013, called 'TYNDP010_130709_Annex-A_InfrastructureProjects_Corrigendum.xlsm' has been checked for differences. No corrections were reported for the five countries selected here.

A.4 Selection

1. All 280 unique project codes that are listed in the TYNDP have been assigned to the country where the (physical) investment takes place. The workbook sheet 'General Information' contains project names that generally include a reference to a geographic location, for example a region or city.[14] Using Google Maps these geographic names have been located on a map. In cases where no geographic name was included, a general Google search for the project was conducted to obtain information on the exact location.
2. Next, the projects were selected that were assigned to Austria, Belgium, France, Germany and The Netherlands. For the project codes assigned to these countries, see Table A.2.

A.5 Estimation

3. ***Unit cost*** estimates have been derived by following the strategies described below. The final unit cost estimates are listed in Table A.3.
   - 3.1 For ***transport*** codes information was found on unit costs from two sources listed in Table A.4. In addition, for several projects we found investment cost mentioned on company websites, or on online (industry) news websites. Given the known number of kilometers involved from the TYNDP, these can be used to arrive at unit cost estimates. The estimates related to pipelines were treated separately from the estimates related to compressor power.
     - 3.1.1 For ***compressor power*** we obtained two estimates of unit costs of which the simple average has been taken.
     - 3.1.2 For ***pipelines***, only data related to onshore pipelines has been used, because all selected projects are onshore. The data pairs of diameter and calculated unit cost have been used in a simple regression analysis in from which a linear relationship has been derived. One pair was excluded as evident outlier. The linear regression has been based on 26 observations. Based on the derived intercept and slope coefficient, the unit cost have been estimated related to the different diameters of pipelines as present in the selected set of projects. The scatterplot of the pipeline diameters and the unit costs is shown in Figure A.1.
   - 3.2 For ***LNG*** investment projects, investment expenditure was found for seven TYNDP projects in other countries then the countries selected. The unit costs have been calculated in relation to the storage capacity of the LNG installation. The lowest value obtained is € 997/m3 and the highest is € 5995/m3. The average over these seven projects (€ 2547/m3) is used as unit cost to calculate the investment costs of the selected projects.
   - 3.3 For ***underground storage*** we distinguish between salt cavity storages and depleted gas fields. The unit of comparison that represents the scale of the projects best is working volume.
     - 3.3.1 We only have information on one ***depleted gas field*** (which is in the selected project list) and we need to estimate the cost of one other project. The working volume of the first project is four times the size of the unknown project. We have chosen to set the cost of the second project to ¼ of the cost of the first project.

[14] The sheet 'Transmission Capacities' indicates which zones are connected. For example from zone 'Hub Austria' to zone 'Hub Czech Republic'. However, this does not provide information where exactly the additional infrastructure is built.

3.3.2 For ***salt cavity*** projects investment costs for two projects were found. The average of the unit cost has been calculated and applied to the salt cavity projects in our list.

4. Based on these unit costs, and the technical information related to the projects for which the costs are unknown, ***total investment estimates*** are made per project.
5. Next, estimations have been made of the ***allocation/distribution*** of the investment numbers to the related industries. For the final percentages see Table A.5. Rui et al. (2012) and the Oil & Gas Journal Data Book (see Table A.4) both indicate the distribution of cost over the categories materials, labor, misc. and land. The first source only contains information on compressor cost; the second source has data on both compressor cost and pipeline cost.
   - 5.1 For ***pipelines***, we use the information on the overall percentage allocation from the Oil & Gas Journal Data Book, and split the information further using the allocation from the Brattle (2010) report. First, material is split into 'fabricated material' and 'machinery and equipment'. Labor is directly related to the 'Construction sector'. 'Land' is related to the 'Real estate sector'. Misc. is split into 'transport and storage', financial intermediation, insurance, and business services.[15]
   - 5.2 For ***compressor*** stations we estimate the distribution percentages in the same way as for pipelines.
   - 5.3 For ***LNG*** we use the same allocation as derived for compressor station investments. Both are relatively material intensive investments.
   - 5.4 For ***underground storage*** we use the distribution as indicated by Brattle (2010), where we split the percentage for financial intermediation and insurance equally over these two sectors. In addition, we set real estate services to 0.7% and business services to 14.3%, which is equal to the percentages recorded for compressor stations and LNG.
6. The allocation/distribution numbers have been applied to the total investment estimates.
7. For each country, the projects are aggregated by type of investment. The resulting investment numbers are presented in Table A.6. In the impact study, only the total investment numbers are used, which are represented in the rows labeled 'Total'

A.6 Summarizing

We translated the investment plans as laid down in the TYNDP 2013-2022 per country where the investment takes place into expenditure packages. First we estimated unit cost based on information from other sources on unit cost and by combining information on investment expenditure with technical information from the TYNDP. From the unit cost estimates we derived total expenditure estimates. Finally, the total cost related to the investment are allocated to (a subset of) the 129 industries that are represented in the EXIOPOL database. These expenditure packages consist of the costs of investment in terms of output bought from different industries.

[15] Misc. is noted to generally include surveys, engineering, supervision, interest, administration and overheads, contingencies, allowances for funds used during construction, and regulatory fees, see Oil & Gas Journal Data Book.

Table A.2. TYNDP project codes* assigned to each of the five selected countries

Austria	Belgium	France	Germany	Netherlands
TRA-N-021	TRA-F-205	TRA-F-036	TRA-F-231	TRA-F-268
TRA-N-035	TRA-N-056	TRA-F-037	TRA-N-069	TRA-N-191
	TRA-N-206	TRA-F-038	TRA-N-207	TRA-N-192
	TRA-N-270	TRA-F-039	TRA-N-208	TRA-N-193
		TRA-F-040	TRA-N-228	
	LNG-N-229	TRA-F-041	TRA-N-232	LNG-N-050
		TRA-F-250	TRA-N-240	
		TRA-F-251	TRA-N-241	UGS-F-052
		TRA-N-042	TRA-N-243	
		TRA-N-043	TRA-N-244	
		TRA-N-044	TRA-N-249	
		TRA-N-045	TRA-N-267	
		TRA-N-046		
		TRA-N-047	UGS-N-001	
		TRA-N-048	UGS-N-005	
		TRA-N-252	UGS-N-049	
		TRA-N-254		
		TRA-N-255		
		TRA-N-256		
		TRA-N-257		
		TRA-N-258		
		TRA-N-269		
		LNG-F-210		
		LNG-N-223		
		LNG-N-225		
		LNG-N-226		
		LNG-N-227		
		UGS-F-004		
		UGS-F-265		
		UGS-N-002		
		UGS-N-003		
		UGS-N-204		
		UGS-N-264		

* The codes can be interpreted as follows: TRA = transport (pipelines, compressors), LNG = liquid natural gas, UGS = underground storage. The letter 'F' indicated that the final investment decision has been taken, the 'N' means that this decision had not been made yet.
The description and all other information related to these project codes can be found in the TYNDP 2013-2022, and specifically in the Excel file 'Annex-A Infrastructure Projects' available on the ENTSOG website.
http://www.entsog.eu/public/uploads/files/publications/TYNDP/2013/TYNDP_Corrigendum/TYNDP010_130709_Annex-A_InfrastructureProjects_Corrigendum.zip

Table A.3. List of unit cost estimates

Type	Sub-type*	Unit cost	Unit
CMP		1.46	M€ / MW
PLN	300 mm diameter – onshore	0.13	M€ / km
PLN	400 mm diameter – onshore	0.40	M€ / km
PLN	500 mm diameter – onshore	0.66	M€ / km
PLN	600 mm diameter – onshore	0.92	M€ / km
PLN	700 mm diameter – onshore	1.18	M€ / km
PLN	800 mm diameter – onshore	1.44	M€ / km
PLN	900 mm diameter – onshore	1.71	M€ / km
PLN	1050 mm diameter – onshore	2.10	M€ / km
PLN	1153 mm diameter – onshore	2.37	M€ / km
PLN	1200 mm diameter – onshore	2.49	M€ / km
LNG		2.55	k€ / m^3
UGS		0.98	M€ / Mm^3

* The sub-types listed here are the diameters of the pipelines that are included in the selected TYNDP 2013-2022 projects. The 1050 and 1153 have been obtained from converting inches to millimeters.

Table A.4. List of unit cost sources

Type	Source	Page	# of reference values	Other remarks
PLN*, CMP*	Kosten-Nutzen-Analyse einer Marktgebietszusammenlegung von GASPOOL und NetConnect Germany nach § 21 GasNZV, a report of PricewaterhouseCoopers Aktiengesellschaft Wirtschaftsprüfungsgesellschaft	11	1 PLN, 1 CMP	
PLN, CMP, LNG	Mott MacDonald (2010), Supplying the EU Natural Gas Market http://ec.europa.eu/energy/international/studies/doc/2010_11_supplying_eu_gas_market.pdf	47 & 48	11 PLN, 1 CMP 4 LNG	PLN is split into onshore and offshore
CMP	Rui Z., P.A. Metz, G. Chen, X. Zhou & X. Wang (2012) Regressions allow development of compressor cost estimation models, Oil and Gas Journal website http://www.ogj.com/1/vol-110/issue-1a/transportation/regressions-allow-full.html	69 & 70	4 CMP	U.S. region specific
TRA, CMP	Oil & Gas Journal Data Book http://books.google.nl/books?id=YmLik9YY4uUC&pg=PA61&source=gbs_toc_r&cad=4#v=onepage&q&f=false		9 PLN, 13 CMP	U.S. region specific

* PLN is short for pipeline, CMP for compressor, both are TRA (transport) projects

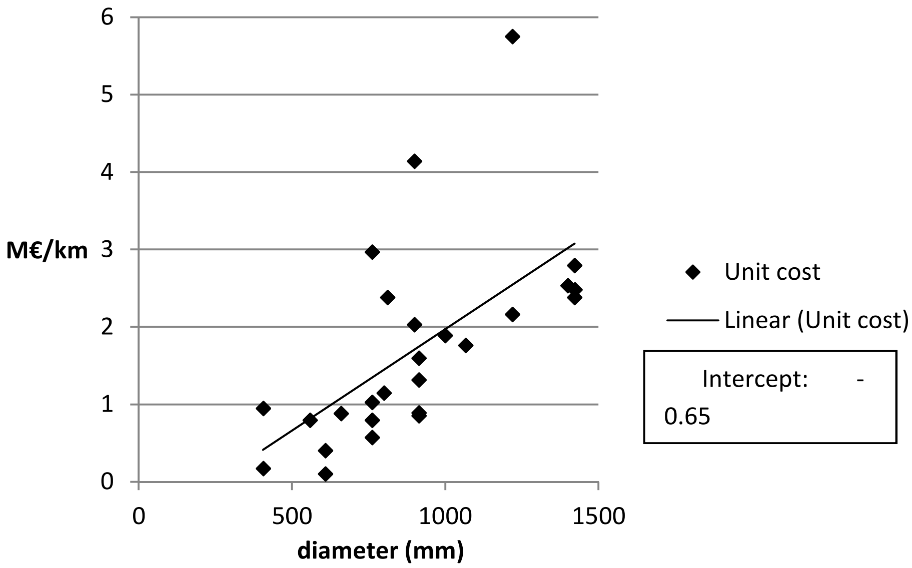

Figure A.1 - Scatterplot of unit costs related to gas pipelines

Table A.5. Allocation / distribution percentages for each of the investment types

Industry code	Industry description	PLN	CMP	LNG	UGS
i28	Fabricated metal	21%	35%	35%	25%
i29	Machinery & equipment	8%	14%	14%	10%
i45	Construction	51%	31%	31%	30%
i60.2	Transport	6%	6%	6%	10%
i65	Financial services	3%	3%	3%	5%
i66	Insurance and pension funding	3%	3%	3%	5%
i70	Real estate activities	5%	1%	1%	1%
i74	Business services	4%	8%	8%	14%

Table A.6. Estimated investment expenditure

		Fabricated metal i28	Machinery & equipment i29	Construction i45	Transport i60.2	Financial services i65	Insurance and pension funding i66	Real estate activities i70	Business services i74	**Total***
Austria	PLN	119	48	293	34	17	17	28	23	**578**
	CMP	46	18	40	8	4	4	1	11	**131**
	LNG	0	0	0	0	0	0	0	0	**0**
	UGS	0	0	0	0	0	0	0	0	**0**
	Total†	**165**	**66**	**333**	**42**	**21**	**21**	**28**	**34**	**710**
Belgium	PLN	33	13	80	9	5	5	8	6	**159**
	CMP	15	6	13	3	1	1	0	4	**44**
	LNG	123	49	108	20	10	10	2	28	**352**
	UGS	0	0	0	0	0	0	0	0	**0**
	Total†	**171**	**68**	**202**	**32**	**16**	**16**	**10**	**38**	**555**
France	PLN	979	392	2403	279	140	140	226	193	**4751**
	CMP	420	168	369	70	35	35	8	96	**1200**
	LNG	915	366	804	152	76	76	18	210	**2615**
	UGS	388	155	465	155	78	78	10	222	**1550**
	Total†	**2702**	**1081**	**4041**	**655**	**328**	**328**	**262**	**721**	**10118**
Germany	PLN	1386	554	3402	395	198	198	320	273	**6726**
	CMP	553	221	486	92	46	46	11	127	**1580**
	LNG	0	0	0	0	0	0	0	0	**0**
	UGS	150	60	180	60	30	30	4	86	**600**
	Total†	**2089**	**836**	**4067**	**547**	**273**	**273**	**335**	**486**	**8906**
Netherlands	PLN	64	26	158	18	9	9	15	13	**312**
	CMP	299	120	263	49	25	25	6	68	**854**
	LNG	123	49	108	20	10	10	2	28	**352**
	UGS	200	80	240	80	40	40	5	115	**800**
	Total†	**686**	**274**	**768**	**168**	**84**	**84**	**28**	**224**	**2318**

* The totals reported in the last column are the estimated investment quantities. The percentage distribution as reported in Table 5 is used to allocate these values to the respective industries.

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